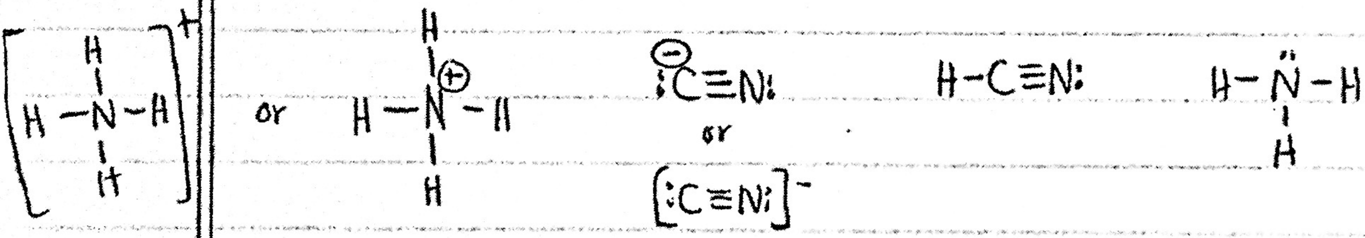
Problem Set #10

① $NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$

NH_3 accepts a proton (H^+) from water so it is a Brønsted-Lowry base. In accepting a proton from water, the concentration of OH^- ions is increased so it is also an Arrhenius base.

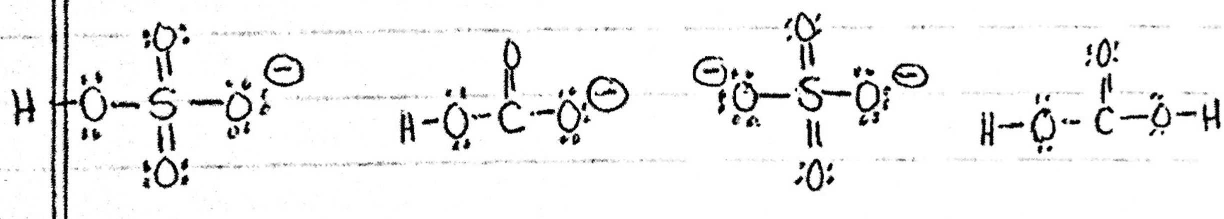
② (a) $NH_4^+{}_{(aq)} + CN^-_{(aq)} \rightleftharpoons HCN_{(aq)} + NH_{3(aq)}$

acid   base   conj. acid   conj. base



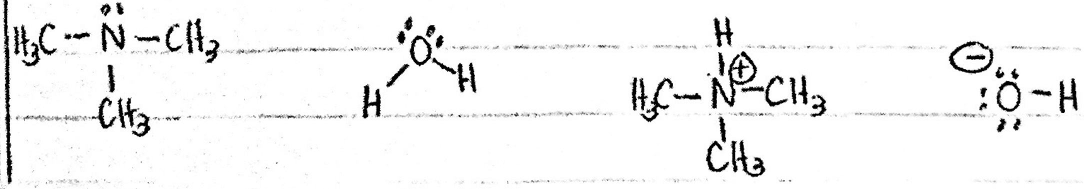
(b) $HSO_4^-{}_{(aq)} + HCO_3^-{}_{(aq)} \rightleftharpoons SO_4^{2-}{}_{(aq)} + H_2CO_{3(aq)}$

acid   base   conj. base   conj. acid



(c) $(CH_3)_3N_{(aq)} + H_2O_{(l)} \rightleftharpoons (CH_3)_3NH^+{}_{(aq)} + OH^-_{(aq)}$

base   acid   conj. acid   conj. base



(d) $HBrO_{(aq)}$ + $H_2O_{(l)}$ $\rightleftharpoons$ $H_3O^+_{(aq)}$ + $BrO^-_{(aq)}$

acid — base — conj. acid — conj. base

3. Complete the following table (show your work):

pH	pOH	[H$^+$]	[OH$^-$]	Acidic or Basic
5.06	8.94	8.7×10^{-6} M	1.1×10^{-9} M	Acidic
10.48	3.52	3.3×10^{-11} M	3.0×10^{-4} M	Basic
2.62	11.38	2.4×10^{-3} M	4.2×10^{-12} M	Acidic
10.88	3.11	1.3×10^{-11} M	7.6×10^{-4} M	Basic

Equations that can be used: $[H_3O^+][OH^-] = 1.0 \times 10^{-14}$; $pH = -\log[H_3O^+]$; $pOH = -\log[OH^-]$; $[H_3O^+] = 10^{-pH}$; $[OH^-] = 10^{-pOH}$; $pH + pOH = 14.00$

4. a) $[H_3O^+] = [HNO_2] = 0.0167\,M$

$pH = -\log[H_3O^+] = -\log(0.0167) = \underline{\underline{1.777}}$

b) $[OH^-] = 2 \times [Ca(OH)_2] = 2 \times 0.0105\,M = 0.0210\,M$

$pOH = -\log(0.0210) = 1.678$

$pH = 14.00 - 1.678 = 12.32$

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$$\% \text{ ionization} = \frac{[H^+]}{[HA]_{ini}} \times 100$$

$$[H^+] = \frac{13.2}{100}(0.100M) = 0.0132\ M$$

$$BrCH_2COOH_{(aq)} \longrightarrow H^+_{(aq)} + BrCH_2COO^-_{(aq)}$$

	$[BrCH_2COOH]$	$[H^+]$	$[BrCH_2COO^-]$
I	0.100	0	0
C	−0.0132	+0.0132	+0.0132
E	0.100 − 0.0132	0.0132	0.0132

$$K_a = \frac{[H^+][BrCH_2COO^-]}{[BrCH_2COOH]} = \frac{(0.0132)(0.0132)}{(0.100-0.0132)} = 2.0\times10^{-3}$$

$[BrCH_2COOH] = 0.100M - 0.0132M = 0.087M$

$[H^+] = [BrCH_2COO^-] = 0.0132M$

(6) $HClO_{(aq)} \longrightarrow H^+_{(aq)} + ClO^-_{(aq)}$

	[HClO]	[H⁺]	[ClO⁻]
I	0.0090	0	0
C	−x	+x	+x
E	0.0090−x	x	x

$\frac{[HA]}{Ka} = \frac{0.0090}{3.0\times10^{-8}} = 300,000$

> 400 Assume x is small

$Ka = \frac{[H^+][ClO^-]}{[HClO]} = 3.0\times10^{-8}$

$\frac{(x)(x)}{0.0090-x} = 3.0\times10^{-8}$

Assume x is small $\Rightarrow \frac{x^2}{0.0090} = 3.0\times10^{-8}$

$x = \sqrt{(0.0090)(3.0\times10^{-8})}$

$x = 1.6\times10^{-5}M = [H^+]$

$pH = -\log(1.6\times10^{-5}) = \underline{\underline{4.78}}$

$[H^+] = [ClO^-] = \underline{1.6\times10^{-5}}M$

$[HClO] = 0.0090M - 1.6\times10^{-5}M \cong \underline{\underline{0.0090M}}$

(7) $BrO^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HBrO_{(aq)} + OH^-_{(aq)}$

	[BrO⁻]	HBrO	OH⁻
I	0.550	0	0
C	−x	+x	+x
E	0.550−x	x	x

$\frac{B}{K_b} = \frac{0.550}{4.0\times10^{-6}} = 137,500$

> 400

Assume x is small

$K_b = \frac{[HBrO][OH^-]}{[BrO^-]} = 4.0\times10^{-6}$

$\frac{(x)(x)}{0.550-x} = 4.0\times10^{-6}$

Assume x is small $\Rightarrow \frac{x^2}{0.550} = 4.0\times10^{-6}$

$x = \sqrt{(0.550)(4.0\times10^{-6})}$

$x = \underline{1.5\times10^{-3}}M = [OH^-]$

$pOH = -\log(1.5\times10^{-3}) = 2.83$

$pH = 14.00 - 2.83 = \underline{\underline{11.17}}$

8. HClO pKa = 7.53 $\Rightarrow K_a = 10^{-7.53} = 3.0 \times 10^{-8}$
$HClO_2$ pKa = 1.96 $\Rightarrow K_a = 10^{-1.96} = 1.1 \times 10^{-2}$

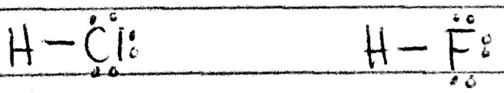
$HClO_2$ is the stronger acid because it has the smaller pKa value & larger Ka. It will ionize more in solution.

conjugate base of HClO $\rightarrow ClO^-$ $K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{3.0 \times 10^{-8}} = 3.3 \times 10^{-7}$

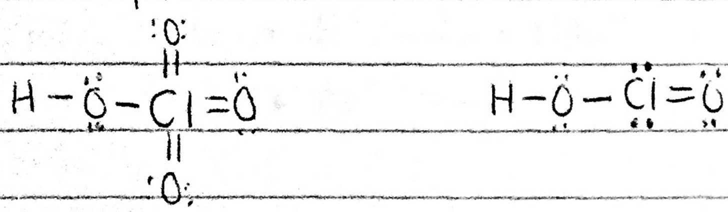
conjugate base of $HClO_2$ $\Rightarrow ClO_2^-$ $K_b = \frac{1.0 \times 10^{-14}}{1.1 \times 10^{-2}} = 9.1 \times 10^{-13}$

ClO^- is the stronger base because its K_b value is larger (the stronger the acid, the weaker its conjugate base).

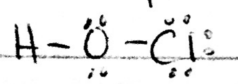
9. (a) HCl is stronger than HF. HCl has a weaker bond than HF (Cl is a larger atom than F) so H comes off more easily.

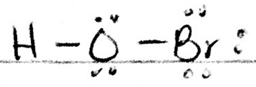


(b) $HClO_4$ is stronger than $HClO_2$. $HClO_4$ has two additional oxygen atom (highly electronegative) and they draw electron density away from Cl which in turn draws electron density away from the O—H bond. Weaker bond, H comes off more easily.



(c) HClO is stronger than HBrO. Cl is more electronegative than Br so it draws more electron density away from the O–H. That weakens the bond and H comes off more easily.





(d) CCl_3COOH is stronger than CH_3COOH. Cl is more electronegative than H and having more electronegative atoms weakens the O–H bond & H comes off more easily (this also helps stabilize the conjugate base).